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# ALFALFA ROOT STUDIES.

By Samuel Garver, *Assistant Agrostologist, Office of Forage-Crop Investigations, Bureau of Plant Industry.*

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## SCOPE OF THE STUDY.

Only within recent years have the crown and the root characters of alfalfa been extensively studied and their relation to environmental factors carefully considered. The physical reasons for an alfalfa plant being resistant to cold or drought remain much in doubt, but the studies of various investigators tend to substantiate the general belief that they may be associated with broad, deep-set crowns, well-developed rooting rhizomes, and numerous branch roots. The publicity that has been given to these particular features has created the rather general impression that there is a much greater difference in the crown and root characters of the hardy and nonhardy alfalfas than actually exists. Plants with pronounced taproots are generally well enough adapted to regions with relatively high mean temperatures, while plants with the more branching root systems are less subject to winterkilling and to injury by rodents or cultivation. The broad, deep-set crowns that are usually associated with the branching root system are popularly considered a decided advantage in cold regions because of the protection afforded to dormant or resting buds. However, artificial protection by means of straw has been found to reduce the mortality of nonhardy plants only slightly under severe winter conditions. This would seem to indicate that cold resistance is an inherent characteristic and is dependent only to a slight degree on the soil protection that is afforded the resting buds. It is the purpose of this bulletin to present data showing more definitely the root characteristics assumed by 'representative varieties of alfalfa under stated field conditions for the relation they may have in the adaptation to environmental conditions. The descriptions of root systems contained herein are of the well-known varieties of alfalfa grown at the Redfield Field Station in South Dakota, under conditions which are probably quite representative of a considerable area of the northern Great Plains. It is recognized that with a different soil, climate, and method of culture, variations may occur, but it is believed that the general conclusions reached in this bulletin would be unchanged. A statement of the conditions under which the plants were grown is deemed desirable and is included with the other data presented.

## FACTORS TENDING TO PRODUCE MODIFICATIONS OF ROOT GROWTH.

Root growth is influenced principally by soil, climate, cultural treatment, and injuries, and to a lesser degree by many other factors. Alfalfa is found growing under conditions of moisture from heavy to light precipitation; on soil types ranging from stiff, heavy clay to almost pure sand; and at altitudes from below sea level to 13,000 feet or more above sea level. Many of the alfalfas that have been introduced into the United States have been grown in different countries hundreds and possibly thousands of years within comparatively small areas and under peculiar soil and climatic conditions. It is hardly to be expected, therefore, that any one location can be found that will provide optimum conditions for the development of the root systems of all the different alfalfas.

### SOIL CONDITIONS.

Root development is influenced by distribution of plant food, soil moisture, soil texture, water table, and hardpan or other hard material. Unusual soil formations in which there is a peculiar distribution of plant food may cause modifications in root growth, because roots have a tendency to remain and develop in the areas of the most favorable conditions of plant food. A number of experiments have been reported showing the influence of such plant-food distribution on root development.

While alfalfa roots are ordinarily able to penetrate compact soil strata, their ability to do so is modified to a considerable degree by moisture conditions. A soil layer may become so hardened by drought that the roots are unable to go through it, but such a condition may be alleviated by the presence of only a small quantity of moisture as a result of opportune rainfall. Compact soil appears to cause greater branching and less pronounced taproots, while the open or porous soils tend to produce long, slender taproots with few branches. The varied development of root systems due to differences in soil texture was noted in seedlings in similar kinds of alfalfa examined at Redfield, S. Dak., and Arlington Farm, Va., in 1916. The seedlings at Redfield showed pronounced taproots and few branches, while those examined at Arlington showed indistinct taproots and a mass of fibrous roots. Roots often terminate or else are deflected from their natural course by very hard material, such as hardpan or stone. On land where the water table is near the surface, the water will act as a barrier to deeper root growth. On irrigated lands root growth is influenced by the time and quantity of water applied.

### CLIMATIC CONDITIONS.

The form and development of the root system is doubtless influenced, to some extent, by the weather conditions that immediately follow seeding. It has been found that alfalfa roots make very rapid early growth, especially at two to three months of age, and it is probably true that the form of the root system is most influenced within this period. Under north-temperate dry-land conditions, young plants from sowings made in early spring or late summer, are generally subject to a long period of cool and moist weather, while late-spring or early-summer sowings have a long period of relatively warm and dry weather in which to make their early growth. No data are available showing the exact effect of these conditions on the growth of the young plant, but they are doubtless of considerable importance.

### CULTURAL FACTORS.

The application of stable manure or commercial fertilizers usually increases root growth. Inoculation with nitrogen-fixing bacteria where these are not already present in the soil also results in a larger root system. That root development is affected by close grazing or frequent cuttings was indicated by a test conducted at Redfield in 1916. A broadcast plat of alfalfa that was seeded August 12, 1915, was selected to determine the influence of frequency of clipping on root growth. This plat had an almost perfect stand, was free from weeds, and had not previously been harvested either for hay or seed. One portion of the plat was harvested 3 times during the season, another 7 times, and the remaining portion 18 times. The result of the different treatments on the vitality of the plants was shown in the mortality that occurred the following winter. (Table 1.)

The plat harvested 3 times was clipped with a mowing machine, while the plats harvested 7 and 18 times during the season were clipped with a lawn mower. The harvested material was removed from the plats in all cases.

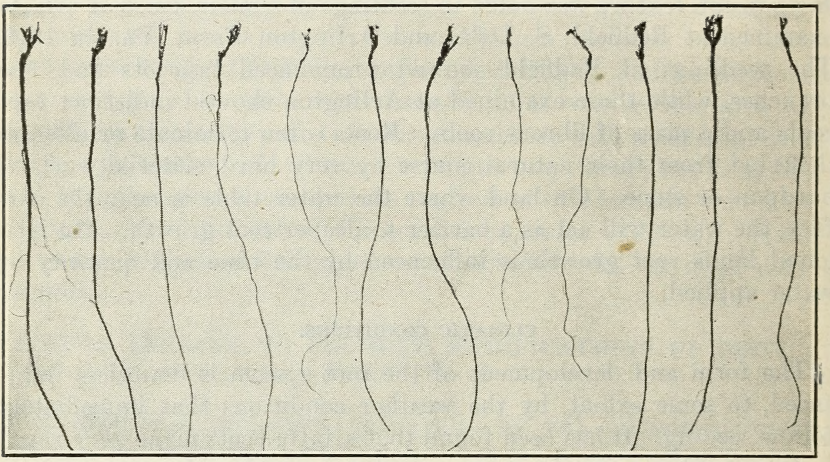

FIG. 1.—Alfalfa roots from a plat clipped three times during the second season.

TABLE 1.—*Effect of frequency of clipping on the vitality of alfalfa plants at Redfield, S. Dak., in 1916 and 1917.*

| Treatment during the season of 1916. | Stand (per cent). | | Mortality, winter of 1916–17 (per cent). |
|---|---|---|---|
| | 1916 | 1917 | |
| Clipped 3 times during season | 100 | 83 | 17 |
| Clipped when 6 inches tall, 7 times during season | 100 | 8 | 92 |
| Clipped 18 times during season | 100 | 1+ | 98+ |

The data given in Table 1 show that the plants from the plats clipped 7 and 18 times were so weakened in vitality by the frequent clippings that they suffered almost complete mortality the following winter. Although considerable winterkilling occurred in the plat harvested three times for hay, a satisfactory stand remained.

In October, 1916, at the close of the period of treatment, 12 plants were removed from each of the plats and the root systems photographed. The plants in each case were taken consecutively from representative areas. The plants from the plat harvested 3 times during the season showed a much larger and stronger root growth than plants from the plats harvested 7 and 18 times. This experiment showed that root development of alfalfa is retarded and vitality reduced by frequent clipping. It is probable that close grazing would have much the same effect. (Figs. 1, 2, and 3.)

Thick seedings which result in crowding, especially during the early life of the plant, tend to produce small crowns and root systems. To determine the relations between space available to the plant and the diameter of the taproot, measurements were made on plants that were removed from the nurseries at Redfield in August and October, 1919. The results are given in Table 2.

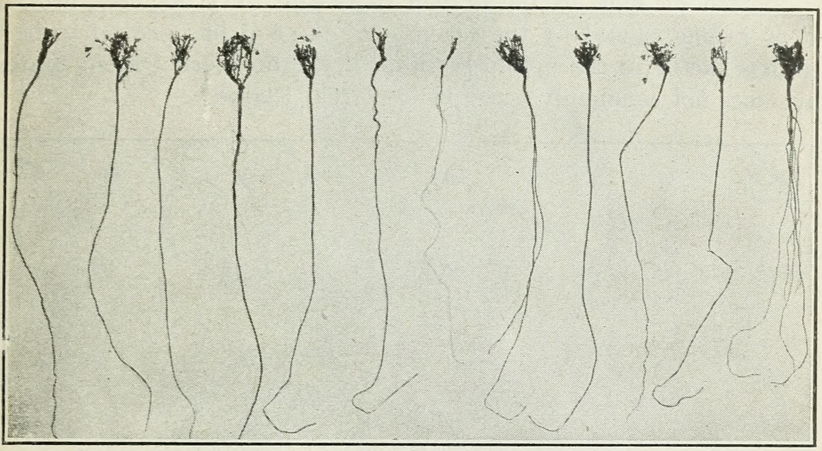

FIG. 2.—Alfalfa roots from a plat clipped seven times during the second season. The alfalfa was clipped each time when 6 inches tall.

TABLE 2.—*Relation of diameter of the taproots of alfalfa plants to thickness of stand in nursery plantings at Redfield, S. Dak., in 1919.*

| Average length of row from which 25 consecutive plants were removed.[1] | Plants considered. |  | Average diameter of each taproot[2] (millimeters). | Average length of row from which 25 consecutive plants were removed.[1] | Plants considered. |  | Average diameter of each taproot[2] (millimeters). |
|---|---|---|---|---|---|---|---|
|  | Average distance apart (inches). | Number. |  |  | Average distance apart (inches). | Number. |  |
| 24 inches | 0.96 | 100 | 9.588 | 41.7 inches | 1.66 | 100 | 11.334 |
| 28 inches | 1.12 | 100 | 9.715 | 48 inches | 1.92 | 50 | 12.065 |
| 30.4 inches | 1.21 | 175 | 10.259 | 64 inches | 2.56 | 25 | 12.700 |

[1] All rows 36 inches apart.

[2] Measurements made 1 inch below the base of the crown.

It is clearly shown in Table 2 that there is an increase in diameter of taproot with the increase in the space between plants, indicating at least in similar varieties of alfalfa that the size attained by the taproot is determined more by the space the plant occupies than by its varietal tendencies. While this is true of the taproot the branch-root development seems to depend more upon the variety than upon the number of plants that occupy a given space.

## ABNORMALITIES DUE TO INJURIES.

Abnormalities may be the result of injuries due to alternate freezing and thawing, to cultural treatment, rodents, insects, or disease. Only the more evident of these will be considered in this connection.

The breaking of roots due to soil heaving is a common occurrence in regions of considerable precipitation and subject to rather suddenly alternating temperatures above and below freezing. The breaking of taproots near the surface in plants with few branch roots may prove fatal, but where there is considerable branching of the taproot near the crown the plant will ordinarily survive, being supported by some of the branch roots that have not been broken. Root injury caused by the heaving of the soil has proved to be a serious factor in the humid sections of the northern United States, but does not commonly occur in the Great Plains.

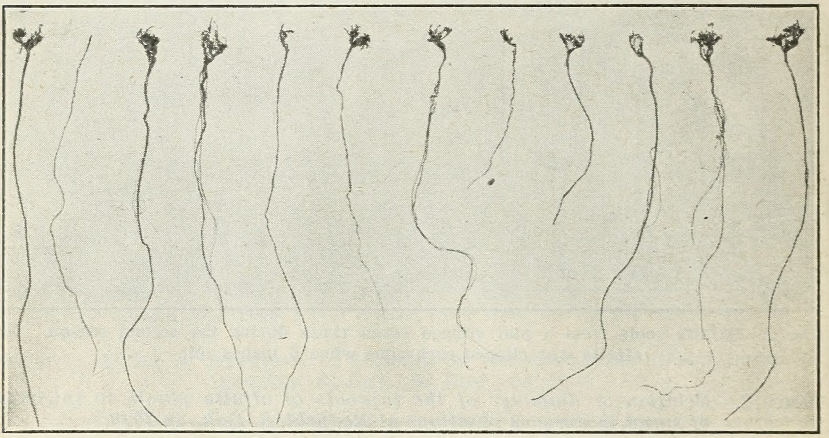

FIG. 3.—Alfalfa roots from a plat clipped 18 times during the second season.

Transplanted plants develop many more branches than where they continue growing under normal conditions. This is because the taproot is generally severed a few inches below the crown, which results in the development of an abnormal number of branch roots. Plants vary in their ability to produce these lateral roots. A very good example of a plant possessing this characteristic to a considerable degree is shown in Figure 4. Six consecutive plants of this same variety of alfalfa grown from seed were removed from the field and the root systems photographed. (Cf. Fig. 15.) Only one of the plants from seed approached in any way, or would in time approach, the type of a reset plant.

Where plants are grown in pots the roots are so closely confined that they assume a spiral form and when transplanted to the field continue to develop abnormally. The root system instead of spreading through the soil remains restricted, and after growing in the field for several months the plants can be easily pulled out. The effect of transferring seedlings of Grimm alfalfa, 40 days old, to flowerpots for a period of 39 days is shown in Figure 5. These plants were taken from the drilled row on June 24, 1920, and put in small pots which were set in the ground. On August 2, 1920, the flowerpots were broken, so that the roots were permitted to spread through the soil. The plants were removed from the field and photographed on October 19. Such treatment appeared to produce distortions of the roots and to promote the growth of many more branches. The effect of limited space for root development on young plants is again illustrated in Figure 6. In this case Grimm alfalfa was sown in small pots on June 24, 1920, and the pots set in the ground. The young seedlings were thinned to one plant to each pot and permitted to grow in this limited area until August 2, when the pots were broken, permitting the roots to spread through the soil. Although the growth of these plants was less than that of the older seedlings (Fig. 5) which were transplanted from the field to the pots, nevertheless the roots showed the same tendencies toward

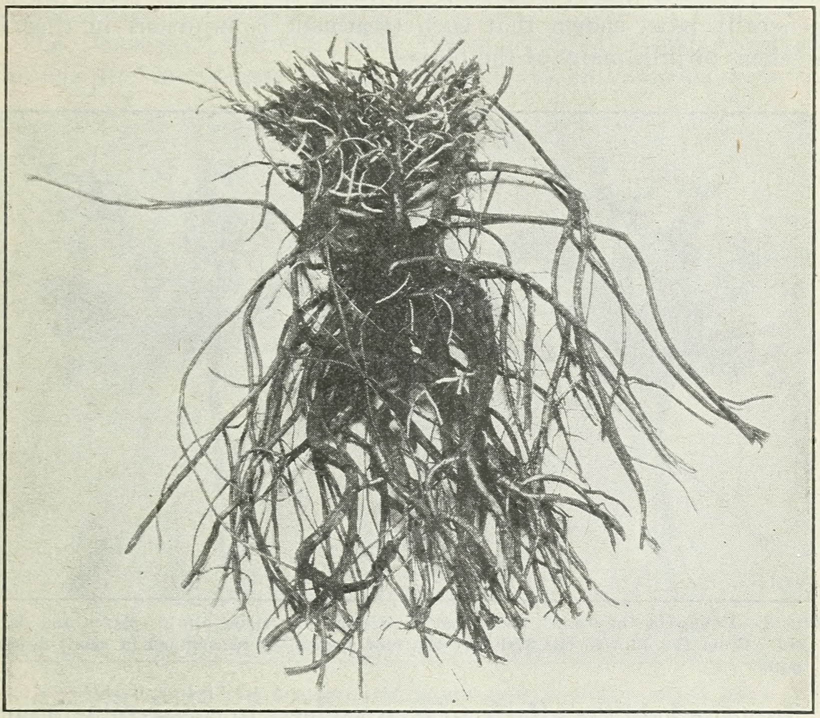

FIG. 4.—Reset plant of yellow-flowered alfalfa (*Medicago falcata*), showing the very extensively branched root system.

branching and distortion. It is, therefore, quite evident in studying transplanted plants—whether from pots to field or from field to field—that due consideration must be given to the effect of such treatment upon root development.

Cultivation modifies the normal root system by injuring or destroying a large number of the surface roots. The use of the disk harrow on alfalfa fields has been recommended frequently on the theory that by means of it soil moisture is conserved, weeds eliminated, and the stand thickened by splitting the crowns. Experiments generally have shown that such treatment is injurious in that it weakens or kills many of the plants.

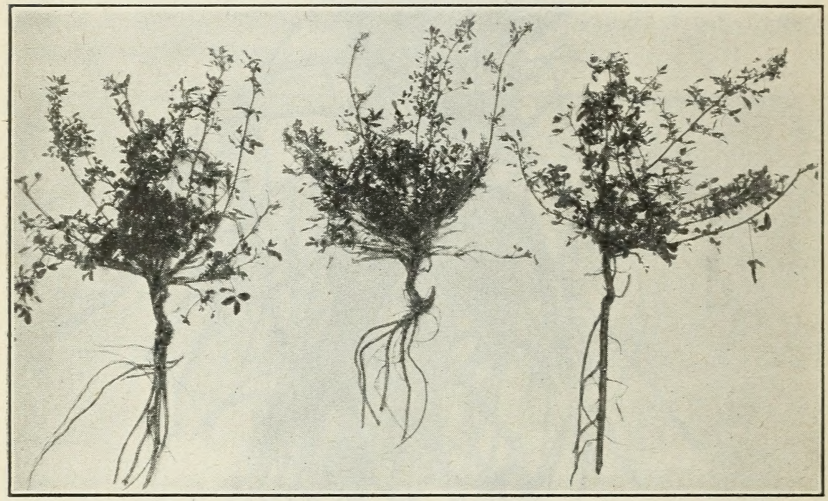

FIG. 5.—Production of branch roots and distortions in Grimm alfalfa plants 166 days old. From the 49th to the 87th day the root systems were confined in small flowerpots.

In many localities alfalfa roots are subject to considerable injury by rodents, such as gophers and mice. When they sever the taproot very close to the crown, as frequently happens, there is no opportunity for the plant to develop side roots, and it soon dies. If the taproot is severed several inches below the crown, the plant often survives and throws out branch roots, behaving much as a transplanted plant does. At Highmore, S. Dak., in 1912 and 1913, several *Medicago falcata* plants had their main roots severed by gophers, yet these plants have continued to live, although much reduced in vitality. *Medicago sativa* plants failed to survive when the taproot was severed so near the crown. Malformations in roots may sometimes be caused by disease, the presence of which can only be determined by close examination.

## VARIETIES STUDIED.

Field studies of the root systems of the more common commercial varieties or strains of alfalfa and of forms of the yellow-flowered species (*Medicago falcata*) have been conducted at the Redfield field station at various times between 1914 and 1920. The varieties and strains[1] taken into consideration include the Peruvian, Poona,[2] southern-grown common, northern-grown common, Turkestan, Grimm, and yellow flowered, and form the basis of the principal part of this study.

The Turkestan, Grimm, and yellow-flowered alfalfas passed through the four-season period from 1916 to 1919, inclusive, with little thinning of stand. The southern-grown common had approximately 22.5 per cent mortality during the period, while the Peruvian and Poona were almost completely winterkilled the first winter. The root systems of 12 consecutive plants of each variety and strain were taken in October, 1916, and photographed. In May, 1917, after growing one season, 25, 75, or 100 plants of each variety and strain were removed consecutively for the purpose of making observations, measurements, and estimates of the more important root characteristics. In August and October, 1919, after growing four seasons, additional data were obtained by taking sets of the same

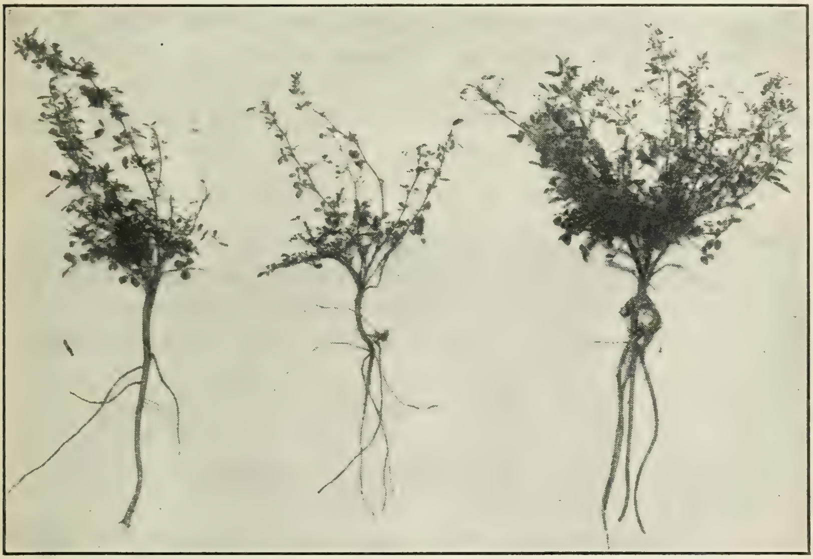

FIG. 6.—Distortions and the production of branch roots in Grimm alfalfa plants 117 days old. These plants were confined in small flowerpots during the first 39 days.

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[1] For definitions and a classification of varieties and strains of alfalfa, see Farmers' Bulletin 757.

[2] An introduction from Poona, India.

number of plants of the same alfalfas. The roots taken in October, 1916, and May, 1917, were from the central portion of 8-rod rows; the roots taken in August, 1919, were from the north ends of the rows and those taken in October, 1919, were from the south ends. Data, unless otherwise stated, were obtained on the first 18 inches of root. This portion of the work was concluded in 1919. It was later found desirable to include data comparing southern-grown common and Grimm with plants of the same age of the prostrate and decumbent forms of pure *Medicago falcata.* In the fall of 1920, after growing six seasons, plants were removed from the nursery. No apparent mortality had occurred among the yellow-flowered plants from the time they were planted in May, 1915, to September, 1920. Only a 5 per cent mortality occurred in the Grimm variety, although some of the surviving plants showed winter injury. In the southern-grown common, 40 per cent of the plants had been killed or very seriously injured. All plants of *Medicago falcata* had pure yellow flowers and there were no evidences of hybridization.

## CONDITIONS UNDER WHICH VARIETIES WERE GROWN.

Root studies were conducted from 1916 to 1919 upon varieties of alfalfa sown May 24, 1916, in drilled rows 36 inches apart and under similar soil conditions. The alfalfas studied in September, 1920, were sown in 42-inch rows in May, 1915. The only treatment to which these rows were subjected was clean cultivation throughout the season and the burning off of the dead stems in the early spring. The soil is fertile, well drained, and well supplied with organic matter and nitrogen-fixing organisms. In order to determine the character of the soil, a trench was opened in the alfalfa nursery in October, 1916, and samples taken at various depths and sent to the Bureau of Soils, United States Department of Agriculture, where a mechanical analysis and determination of calcium carbonate were made. The results obtained are shown in Table 3.

TABLE 3.—*Mechanical analyses and determination of calcium carbonate in representative soils at the Redfield Field Station, S. Dak.*

| Depth from which soil sample was taken.[1] | Description. | Constituents (per cent). | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Lime ($CaCO_3$). | Fine gravel, 2 to 1 mm. | Coarse sand, 1 to 0.5 mm. | Medium sand, 0.5 to 0.25 mm. | Fine sand, 0.25 to 0.10 mm. | Very fine sand, 0.10 to 0.05 mm. | Silt, 0.05 to 0.005 mm. | Clay, 0.005 to 0 mm. |
| 0 to 1 foot | Silty clay loam | 0.25 | 0 | 0.3 | 0.4 | 11.6 | 13.1 | 52.1 | 22.1 |
| 1 to 4 feet | Clay | 13.63 | 0 | .1 | 0 | 1.1 | 1.9 | 24.7 | 72.2 |
| 4 to 5 feet | Silt loam | 11.45 | .9 | 1.0 | .4 | 1.0 | 2.2 | 81.4 | 13.2 |
| 5 to 8 feet | Clay | 6.97 | 0 | 0 | 0 | .2 | .3 | 33.5 | 66.0 |
| 8 to 10 feet | do | 6.31 | 0 | 0 | 0 | 1.2 | 1.0 | 21.6 | 76.1 |

[1] Samples, as listed in the table, are averages for the depths stated.

The analyses showed a high percentage of lime, especially at a depth of 1 to 5 feet. The surface foot is a fairly open black silty clay loam. At a depth of 1 to 4 feet it consists of a high percentage of fine soil particles and is fairly compact. A silty loam of a soft, shaly nature occurs at a depth of 4 to 5 feet. From 5 to 10 feet the soil is a clay that is apparently easily penetrated by alfalfa roots.

Investigations indicate that the type of root growth is pretty definitely determined during the first few months, and for this reason a summary of temperature and precipitation records is presented as indicating in a general way the moisture available to the plant (Table 4).

TABLE 4.—*Summary of precipitation and temperature records at Redfield, S. Dak., from April, 1916, to March, 1917.*

| Items of comparison. | Growing season, 1916. | | | | | Fall conditions, 1916. | | | Winter conditions, 1916–17. | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. | Jan. | Feb. | Mar. |
| Total precipitation, inches.. | 1.11 | 5.13 | 3.56 | 2.01 | 5.19 | 1.42 | 0.55 | T | 2.13 | 2.38 | 0.8 | 2.25 |
| Departure from normal, inches................ | −.65 | +2.22 | +.82 | −.95 | +1.97 | −.45 | −.8 | −0.4 | +1.75 | +2.09 | +.37 | +1.6 |
| Average temperature, °F... | 43 | 55.6 | 62.4 | 78.8 | 70 | 58.2 | 43.8 | 30.9 | 7.8 | 5 | 4 | 23.9 |
| Departure from normal, °F................ | −1.7 | 0 | −3.2 | +8.5 | .6 | −1 | 3 | −.5 | −9.9 | −7 | −8.4 | −5.3 |
| Total precipitation, inches.. | 17.00 | | | | | 1.97 | | | 7.55 | | | |
| Departure from normal, inches................ | +3.41 | | | | | −1.65 | | | +5.81 | | | |

These data show that the season was favorable for alfalfa growth. There was an abundance of rainfall and cool weather in early spring and as late as early July. Drought then became gradually more pronounced, and unusually high temperatures prevailed until the middle of August, when rains occurred, resulting in late summer and fall growth. It would appear that conditions were favorable for a well-established root system in early spring and during the summer.

## DIFFICULTIES ENCOUNTERED IN GETTING COMPARABLE DATA.

The chief difficulty encountered in obtaining comparable data on root systems in old fields of the less hardy alfalfa varieties and strains under the more severe environmental conditions is in making proper allowance for the doubtless accentuated growth of the surviving plants. The more susceptible plants having been winter-killed, the data obtained are from the more hardy individuals that have been given more room, permitting a greater root growth. In these studies at Redfield it was recognized that this thinning of stands and its effect on root growth was a factor that must be taken into consideration. In order to obtain a more thorough conception of its effect data were obtained on the extent of the mortality between 1917 and 1919, measurements being also made showing the increase in root diameter during this period. The data obtained showed rather conclusively that the dying of the plants in the field resulted in a larger taproot growth of the survivors and that the roots of the plants surviving were of a more branching type. A decrease in the stands of the less hardy alfalfas, during a growth of four seasons, amounted to as much as 22.5 per cent and was found to be accompanied by an increase in root diameter of 74.9 per cent. while with hardy alfalfas where there was almost no mortality the increase was appreciably less. This amounted to 64.2 per cent in Turkestan alfalfa and to 55.8 per cent in the Grimm variety. As data which will be presented later show no distinguishing differences between these varieties and strains in the size of the taproot, it is apparent that the greater increase in root diameter of the nonhardy alfalfa was probably due to the thinning of the stands, which not only eliminated the small plants but permitted a greater root growth of the surviving plants. (Figs. 7, 8, and 9.)

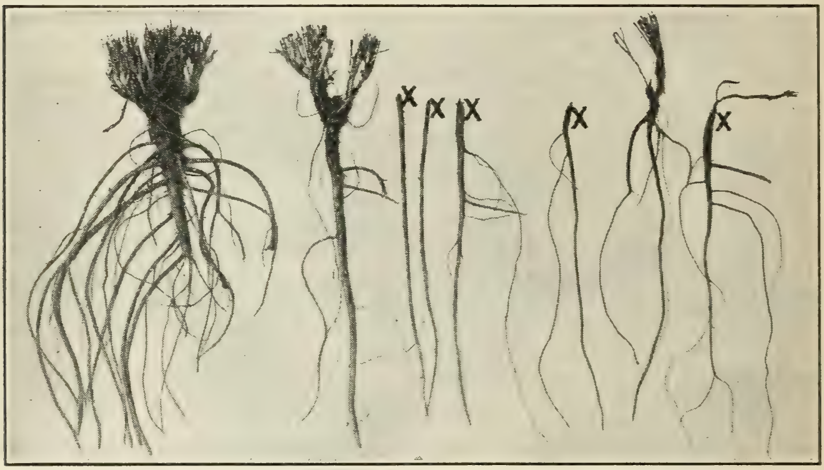

FIG. 7.—Root systems of plants of southern-grown common alfalfa (*Medicago sativa*), indicating the large percentage of mortality occurring in this strain during the 6-year period from 1915 to 1920, inclusive. Roots marked × represent dead plants.

## CHARACTERISTIC ROOT SYSTEMS OF SOME OF THE WELL-KNOWN VARIETIES OF ALFALFA.

An attempt is here made to describe and compare in a simple way and to illustrate with photographs the types of root systems that are characteristic of the best-known varieties of alfalfa. By so doing it is hoped to convey a better idea of their points of similarity and their differences than now appears to prevail.

### NONHARDY ALFALFAS.

As the term indicates, the group of nonhardy alfalfas includes those varieties and strains that can be grown successfully only in regions having such a mild climate that little or no winterkilling occurs. The Peruvian alfalfa is the only well-known variety of this group in the United States, and the area to which it is adapted is limited to sections where the minimum temperature seldom falls below 10° F.

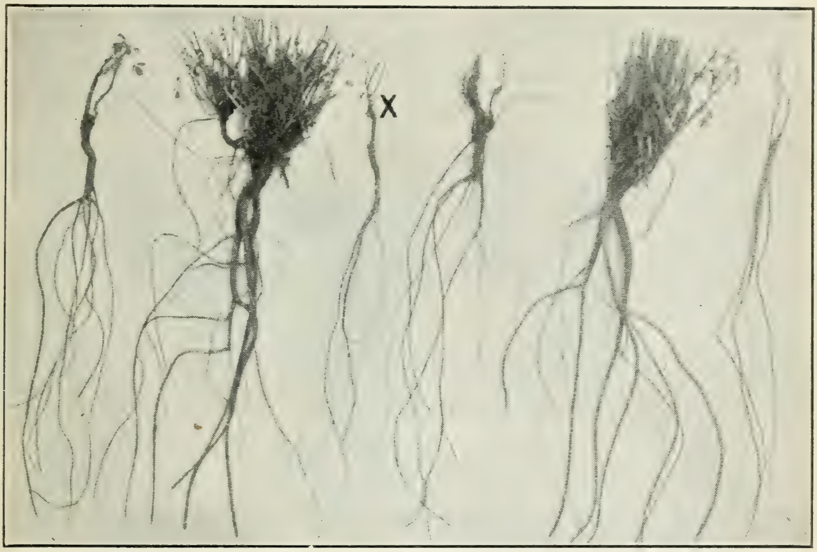

FIG. 8.—Root systems of plants of Grimm alfalfa, indicating considerable injury but only a small percentage of mortality in this variety during the 6-year period from 1915 to 1920, inclusive. The root marked X represents a dead plant.

### PERUVIAN ALFALFA.

As few plants of the Peruvian variety survive the winter at Redfield, it was necessary to make observations on roots of plants of one season's growth. This is a purple-flowered alfalfa having a narrow, upright crown, few crown branches, and only occasional rooting rhizomes. The taproots are very prominent, and branch roots are few, small, irregularly distributed, and seldom rebranched. Fibrous roots, which are generally more abundant near the surface in the hardier alfalfas, are sparse and uniformly distributed over the entire root system. With the exception of the Poona alfalfa, the Peruvian alfalfa made the smallest root growth in the first season of any of the alfalfas studied at Redfield. The differences between the root systems of this variety and other varieties and strains of one season's growth are well shown by comparing Figure 10 with Figures 11 to 14, inclusive.

### POONA ALFALFA.

In 1913 the United States Department of Agriculture received seed of a distinct variety of *Medicago sativa* from west-central India. This alfalfa, which has been given the name of Poona, from its source, has proved to be even less hardy than the Peruvian variety. Poona alfalfa seeded at Redfield in 1915 suffered complete mortality the following winter, while Peruvian seeded under the same conditions had a small percentage of survival. The variety is characterized by narrow, upright crowns, few crown branches, and very few, if any, rooting rhizomes. It differs from most other varieties in the almost entire absence of branch roots on the upper portion of the taproot. At a depth of 8 to 12 inches, however, branch roots are relatively profuse. Fibrous roots are sparse and rather uniformly distributed over the root system. The differences between roots of one season's growth of this and other varieties and strains are shown by a comparison of Figure 11 with Figures 10 and 12 to 14, inclusive.

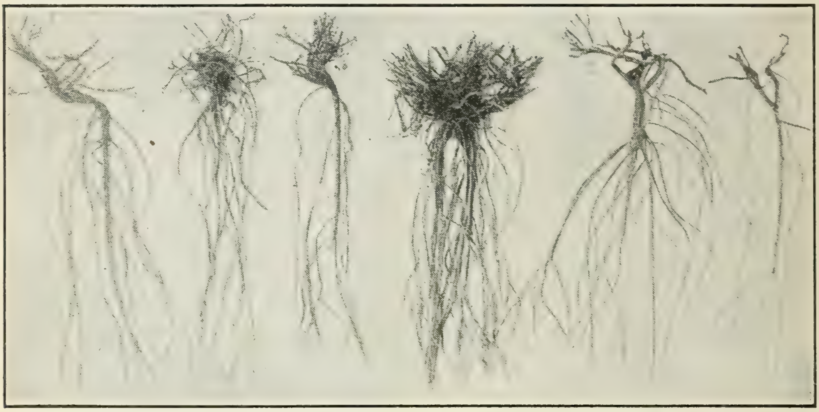

Fig. 9.—Root systems of decumbent plants of yellow-flowered alfalfa (*Medicago falcata*). No winterkilling and very little injury occurred in this alfalfa during the 6-year period from 1915 to 1920, inclusive.

### COMMON ALFALFAS.

The common alfalfas include the purple-flowered strains generally grown throughout the western United States. It is believed that practically all of them have a common lineage, being descended from stock introduced into California during the early history of that State. For convenience they may be arbitrarily placed in two groups: Southern-grown common and northern-grown common.

#### SOUTHERN-GROWN COMMON ALFALFA.

Having comparatively small, upright crowns and pronounced taproots, southern-grown common alfalfa also has relatively few branch roots, fibrous roots, and rooting rhizomes. The crowns are somewhat larger than in the less hardy varieties, such as Poona and Peruvian, but smaller than in Grimm and Turkestan. The taproot is prominent, grows vertically downward, and tapers slowly. In diameter there is no distinguishing difference between this variety, the Turkestan, and the hybrid alfalfas, as is shown in Table 5.

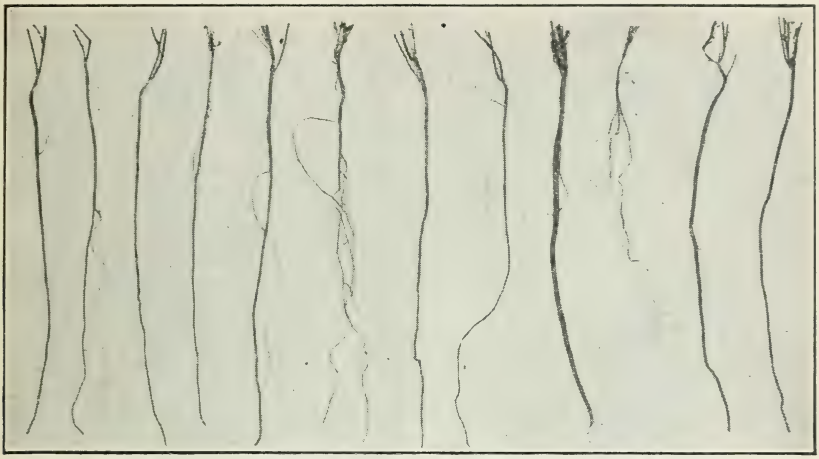

FIG. 10.—Root systems of Peruvian alfalfa plants, the growth of one season.

As a result of the greater mortality in southern-grown common alfalfa, each plant had more space than the ordinary varieties. It is probable that with the same amount of space the differences in root diameter would be somewhat greater than is shown in the table.

TABLE 5.—*Average diameter of taproots of different kinds of alfalfa at Redfield, S. Dak., in 1917, 1919, and 1920.*

[Studies in 1917 and 1919 made on 1916 seedings; in 1920, on 1915 seedings.]

| Kind. | Number of plants observed, each date. | Measurements made within 1 inch of the crown. | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Average root space per plant (inches). | | | | Average diameter of taproots (mm.). | | | |
| | | May, 1917. | August, 1919. | October, 1919. | September, 1920. | May, 1917. | August, 1919. | October, 1919. | September, 1920. |
| Southern-grown common | 100 | 1.08 | 1.30 | 1.74 | | 5.52 | 9.72 | 5.60 | |
| Turkestan | 25 | 1.36 | 1.60 | 1.04 | | 6.60 | 11.16 | 10.52 | |
| Grimm | 75 | 1.49 | 1.30 | 1.56 | | 6.84 | 9.94 | 11.25 | |
| Southern-grown common | 32 | | | | 2.12 | | | | [a] 11.56 |
| Grimm | 32 | | | | 1.56 | | | | 12.43 |
| Decumbent yellow flowered | 19 | | | | 6.31 | | | | 11.00 |
| Prostrate yellow flowered | 22 | | | | 2.18 | | | | 8.50 |

[a] The large root diameters in southern-grown common plants in 1919 may be accounted for by the high mortality occurring between 1916 and 1919, which probably left the larger and stronger ones.

Division of the taproot occurs less frequently than in the Grimm and Turkestan varieties.

Table 6 tends to show that branch roots in the southern-grown common alfalfa are perceptibly less abundant than in the Turkestan and Grimm. They are, however, relatively large, thus making the branching system appear somewhat more prominent (Table 7, column 3) than the number recorded would indicate.

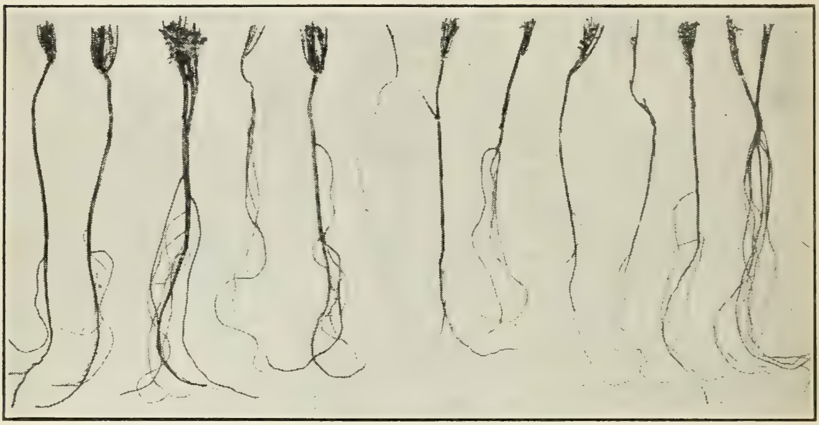

FIG. 11.—Root systems of plants of Poona alfalfa (*Medicago sativa*), the growth of one season.

TABLE 6.—*Number of branch roots occurring in different kinds of alfalfa at Redfield, S. Dak., in 1917, 1919, and 1920.*

[Studies in 1917 and 1919 made on 1916 seedings; in 1920, on 1915 seedings.]

| Kind. | Plants observed. | | Counts of branch roots 2 mm. or more in diameter from crown to 18 inches below. | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | May, 1917; 1 season's growth. | | August, 1919; 4 seasons' growth. | | October, 1919; 4 seasons' growth. | | September, 1920; 6 seasons' growth. | |
| | Number, each date. | Average distance apart (inches). | Mortality, 1916–17 (per cent). | Average branch roots per plant. | Mortality, 1916–19 (per cent). | Average branch roots per plant. | Mortality, 1916–19 (per cent). | Average branch roots per plant. | Mortality, 1916–19 (per cent). | Average branch roots per plant. |
| Southern-grown common | 100 | 1.37 | None. | 2.15 | 13 | 3.52 | 32 | 3.68 | | |
| Turkestan | 25 | 1.32 | None. | 3.88 | None. | 5.20 | 9 | 4.24 | | |
| Grimm | 75 | 1.45 | None. | 4.33 | 5 | 4.34 | 4 | 3.96 | | |
| Southern-grown common | 32 | 2.12 | | | | | | | 40 | [1] 5.78 |
| Grimm | 32 | 1.56 | | | | | | | 5 | 5.93 |
| Decumbent yellow flowered | 19 | 6.31 | | | | | | | None. | 11.47 |
| Prostrate yellow flowered | 22 | 2.18 | | | | | | | None. | 6.90 |

---

[1] The large number of branch roots in southern-grown common alfalfa is probably due to extensive plant mortality between 1915 and 1920, which probably left the plants with the greater branch-root development.

The angle which the branch roots form with the taproot is quite similar in all the alfalfas studied, with the exception of the yellow-flowered variety where this angle is somewhat greater. Fibrous roots, while more numerous than in Peruvian and Poona alfalfas, are relatively sparse and well distributed over the root system, differing in this respect from the hardier varieties. (Table 7, column 4.) Rooting rhizomes are fewer and not so well developed as in northern-grown common, Turkestan, or Grimm. (Fig. 12.)

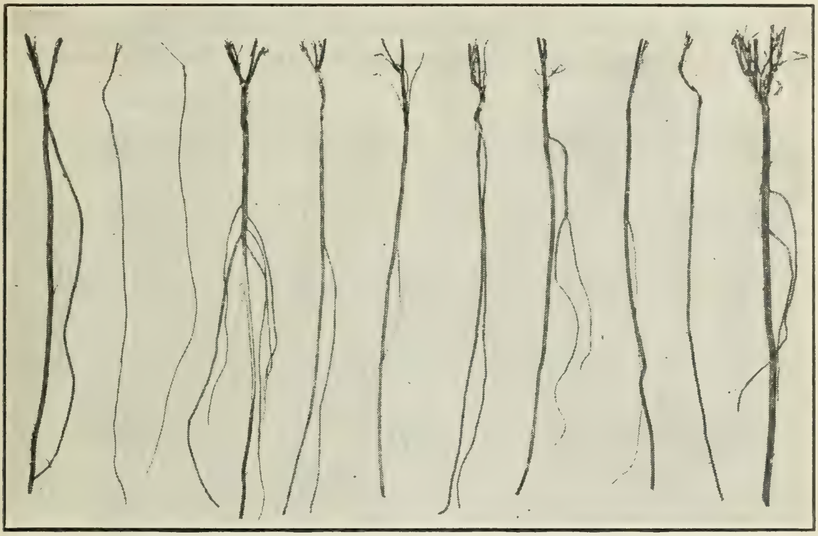

FIG. 12.—Root systems of southern-grown common alfalfa plants, the growth of one season.

TABLE 7.—*Estimates of the prominence of the branch roots and the relative abundance of fibrous roots in different kinds of alfalfa at Redfield, S. Dak.*

| Kind. | Number of plants considered. | Prominence of branch roots. | Relative abundance of fibrous roots. |
|---|---|---|---|
| Southern-grown common | 300 | [1] 85 | [2] 85 |
| Northern-grown common | 75 | 92 | 92 |
| Turkestan | 75 | 96 | 97 |
| Grimm | 225 | 96 | 97 |
| Decumbent yellow flowered | 19 | [3] 100 | 98 |
| Prostrate yellow flowered | 22 | 98 | [4] 100 |

[1] Few branch roots; prominent taproots.
[2] Rather sparse.
[3] Branch roots numerous; taproot indistinct.
[4] Very abundant.

### NORTHERN-GROWN COMMON ALFALFA.

In the United States the hardy strains of common alfalfa are largely the result of selective acclimatization, although in many cases the presence of a small percentage of *Medicago falcata* blood has contributed to the hardiness of these strains.

Most of the seed that is placed on the market is produced in Montana and the Black Hills region of South Dakota. The root systems of this alfalfa are fairly uniform and intermediate between the root system characteristic of southern-grown common alfalfa and that of the hardier varieties, such as Turkestan and Grimm. The taproot is quite distinct and branch roots are most prominent at 1½ to 4 inches below the crown. This is somewhat nearer the surface than is characteristic of the southern-grown strains and almost identical with the Turkestan and Grimm. In number and prominence of branch roots, the northern-grown common alfalfa exceeds the southern grown, but does not equal the Turkestan and Grimm. The distinguishing differences in these respects, however, are usually so slight that they can be noted only by examining many plants. (Fig. 13.)

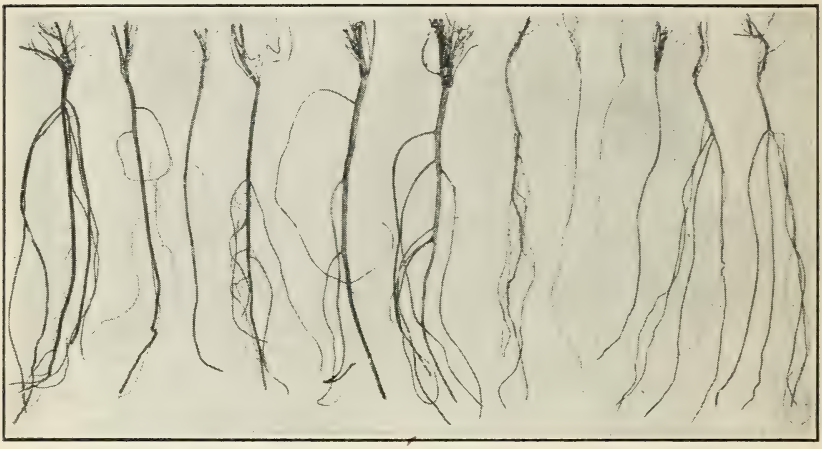

FIG. 13.—Root systems of northern-grown common alfalfa plants, the growth of one season.

### TURKESTAN ALFALFA.

Strains of Turkestan[3] alfalfa have been under test for a number of years in the northern Great Plains region, and certain introductions have proved hardy and quite productive. They are characterized by broad, deep-set crowns and more numerous crown branches than the common and nonhardy alfalfas. The taproots are relatively shorter, more tapering, and less distinct than in common, Peruvian, and Poona. The diameter of the taproot somewhat exceeds that of the nonhardy alfalfas studied, but as measurements show, it is somewhat less in plants of one season's growth than in the Grimm alfalfa.

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[3] The root systems of plants of Turkestan alfalfa studied at Redfield were from plats sown with seed that was the result of several seed generations in the northern Great Plains region. The original seed was of S. P. I. No. 991, which was collected under the direction of the U. S. Department of Agriculture at Tashkend, Turkestan, in 1898.

In plants of four season's growth the diameter of the taproot of Turkestan alfalfa is slightly greater than that of the Grimm. Branch roots are abundant and prominent, occurring in greatest profusion at 1½ to 4¼ inches below the crown. The average angle of divergence is greater than in any of the alfalfas studied except that of *Medicago falcata*. Fibrous roots are very abundant and most numerous within 5 inches of the surface. Well-developed rooting rhizomes are common. The Turkestan alfalfa differs from the nonhardy varieties in possessing decidedly larger numbers of branch roots and fibrous roots; but, as shown by the data presented in Tables 5, 6, and 7, the differences in the more pronounced root characters between this variety and Grimm are not sufficient to distinguish one from the other.

### GRIMM ALFALFA.

Grimm alfalfa is the best-known variety of variegated alfalfa in the United States. It is a cross between *Medicago falcata* and *Medicago sativa* and was brought to Minnesota from Germany in 1858. It has been grown under rather severe conditions since that time, and as a result only the most hardy plants have survived. The plants studied at Redfield were of stock that had proved hardy and productive.[4] The root systems showed greater irregularity than other varieties studied, probably owing to the fact that this alfalfa is a hybrid.

In order to observe root development in considerable detail, a trench several feet in depth was dug along one of the nursery rows. Many of the taproots were found to divide, some near the surface and others at considerable depths. The branch roots diverged from the taproot at angles varying from 50° to 80° for about 12 inches, when most of them turned vertically downward, being only slightly deflected by a compact soil stratum at a depth of 3 to 4 feet.[5] At this point more than the normal amount of branching occurred. As the next 12 inches of soil was somewhat more friable, the roots seemed to experience no difficulty in penetrating it. Small channels occurred throughout the soil which contained either partially decomposed roots or showed evidence of having been root passages. Branch roots, although most abundant near the surface, were found all along the taproot. Small fibrous roots occurred over the entire root system, being especially numerous within 5 or 6 inches of the crown. In a few instances the fibrous roots were traced to a depth of 9 feet 7 inches, where they terminated in a rather dry clay stratum. The area occupied by the roots of a single 3-year-old plant was estimated to be 3 feet in diameter and 10 feet deep.

---

[4] This seed (S. P. I. No. 29988) was harvested from a field 40 years old in Carver County, Minn. It was purchased by the Department of Agriculture from A. B. Lyman, of Excelsior, Minn., in February, 1911.

[5] Compare with data in Table 3.

Taproots of Grimm alfalfa taper more rapidly than those of less-hardy strains, but just below the crown there appears to be only a slight difference in the diameters of the taproots of the different varieties, as is shown in Table 5. In the number of branch roots the Grimm alfalfa exceeds the southern strains, as is indicated in Table 6. Grimm and Turkestan alfalfa show somewhat greater angles of divergence of the branch roots than southern-grown common, but the variations are hardly sufficient to constitute distinguishing characteristics. As is shown in Table 7 the Grimm alfalfa differs from the less hardy varieties by having more numerous fibrous roots, which are most abundant within 5¼ inches of the crown. In the southern-grown strains the fibrous roots are relatively sparse and quite uniformly distributed over the root system. Rooting rhizomes are often well developed; but, in this respect, the Grimm alfalfa is not quite so marked as the yellow-flowered kind. (Figs. 14 and 15.)

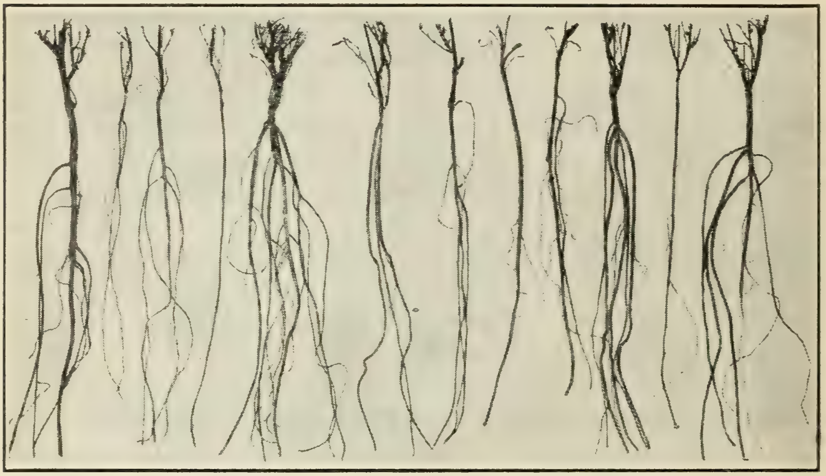

FIG. 14.—Root systems of Grimm alfalfa plants, the growth of one season.

The root systems of Grimm alfalfa and the strain of Turkestan alfalfa studied are so similar that even the closest examination will not serve to distinguish between them. The chief difference is the greater uniformity of the root systems in the Turkestan variety. It appears possible, however, to distinguish the southern-grown common alfalfa from either of these varieties by close study of the root systems of a large number of plants. This can not be done where only one or two are available for study.

### YELLOW-FLOWERED ALFALFA.

While several introductions of yellow-flowered alfalfa (*Medicago falcata*) have been made since 1897, none of them is of commercial importance. As a whole, they are characterized by many branch roots, which taper so gradually that they are often as large at a distance of 2 or 3 feet as they are at the point of origin. They usually extend to a greater depth than the taproot—where it is present. Fibrous roots are abundant, especially near the surface. Crown branches and rhizomes are small and numerous. Based upon manner of growth, these alfalfas may be divided into three general classes: (1) Erect, with narrow crowns, upright stems, and root system, like *Medicago sativa;* (2) prostrate, with broad, deep-set crowns, prostrate stems, and a much-branched root system; and (3) decumbent, intermediate between Nos. 1 and 2 as to root system and general habit of growth. At Redfield the roots of the yellow-flowered alfalfa seldom reach a depth greater than 5 feet, while Grimm alfalfa, grown under similar conditions, attains a depth of 10 feet.[6]

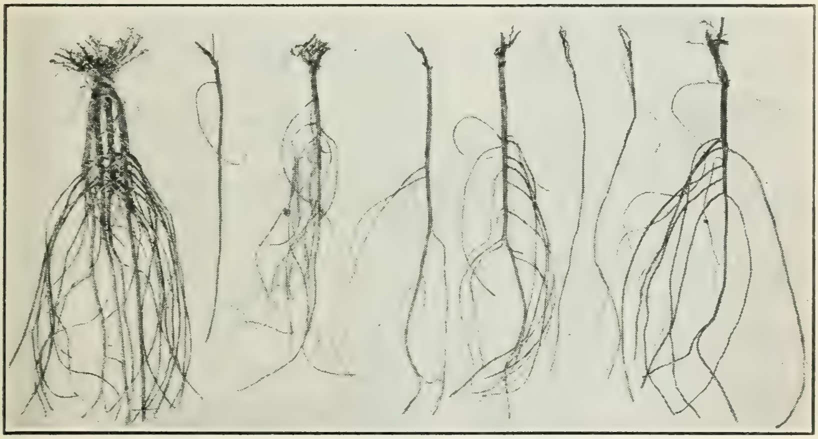

FIG. 15.—Root systems of plants of yellow-flowered alfalfa (*Medicago falcata*), the growth of two seasons.

*Erect yellow-flowered alfalfa.*[7]—The erect form of *Medicago falcata* is distinguished from the other types of the species by the shape of the crown and the prominence of the taproot, which is relatively small but quite as distinct as that of the Grimm alfalfa. The branch roots are more numerous, smaller, and more slowly tapering.

---

[6] Frank N. Meyer reports roots of large size growing in open sandy soils on the banks of the Tom River near Tomsk, Siberia. Some plants were found with roots fully 2 inches in diameter at the crown and more than 1 inch in diameter at a depth of 14 feet. A few of the roots were found to extend to a depth of 33 feet.

[7] S. P. I. No. 20721 (*Medicago falcata*), from Samara Province, Russia, as found wild. (See S. P. I. No. 20726.)

Figure 15 shows roots of one of the most upright, narrow-crowned forms of yellow-flowered alfalfa that has been introduced. Seven of these plants have distinct taproots and five show a decided branching tendency. The branch roots are put forth obliquely and form a somewhat greater angle with the taproot than is the case with Grimm and Turkestan. The crown is quite similar to that of the Grimm except that the crown branches and rhizomes are smaller and more numerous. Fibrous roots are relatively abundant.

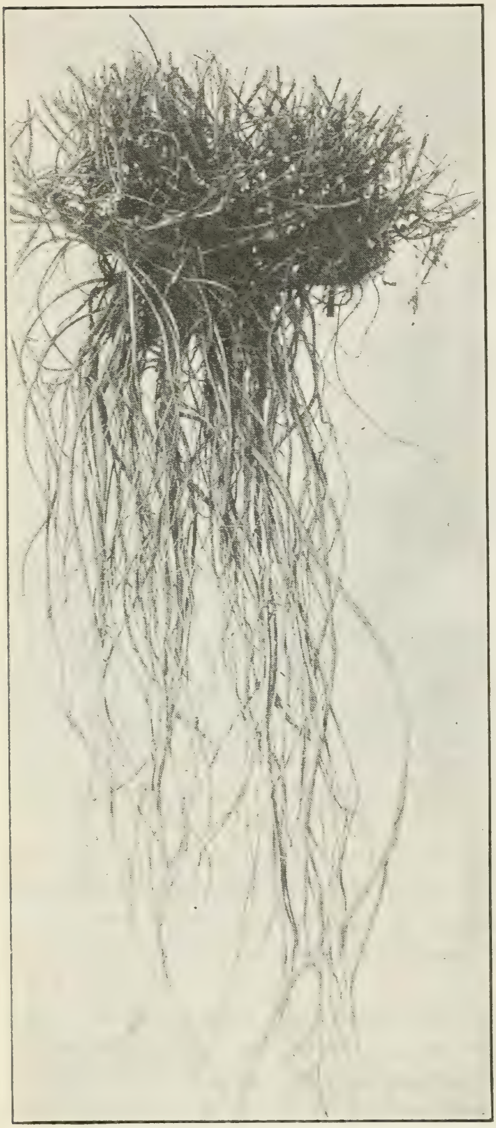

FIG. 16.—Root system of a prostrate yellow-flowered alfalfa plant, the growth of six seasons.

*Prostrate yellow-flowered alfalfa*.[8]—The prostrate yellow-flowered alfalfas are characterized by very broad deep-set crowns, well-developed rhizomes, and dense root systems. Taproots are either not apparent or are very short and indistinct. As shown in Table 6, branch roots are somewhat more numerous than in *Medicago sativa*. The angle that the branch roots form with the taproot is somewhat greater than with purple-flowered and hybrid alfalfas. A large percentage of the branch roots originate from the rhizomes, thus suggesting that the highly developed root system is at the expense of the taproot and its branches. Rhizomes are longer and more branching than in the common or variegated alfalfas. Fibrous roots occur in considerable abundance in all parts of the root system. (Figs. 16 and 17.)

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[8] The alfalfa considered is S. P. I. No. 20717 (*Medicago falcata*), from Kharkof Province, southwestern Russia, a wild form.

*Decumbent yellow-flowered alfalfa.*[9]—The decumbent form of yellow-flowered alfalfa is intermediate between the two forms previously considered. The type is represented by S. P. I No. 33465. The taproots are indistinct, short and rapidly tapering and slightly smaller than the southern-grown common and Grimm varieties, as is shown in Table 5. This strain has the most extensive root system of all the alfalfas studied. The rhizome development is greater than any of the alfalfas except the prostrate yellow-flowered. Fibrous roots are relatively abundant. (Table 7, Figs. 9 and 18.)

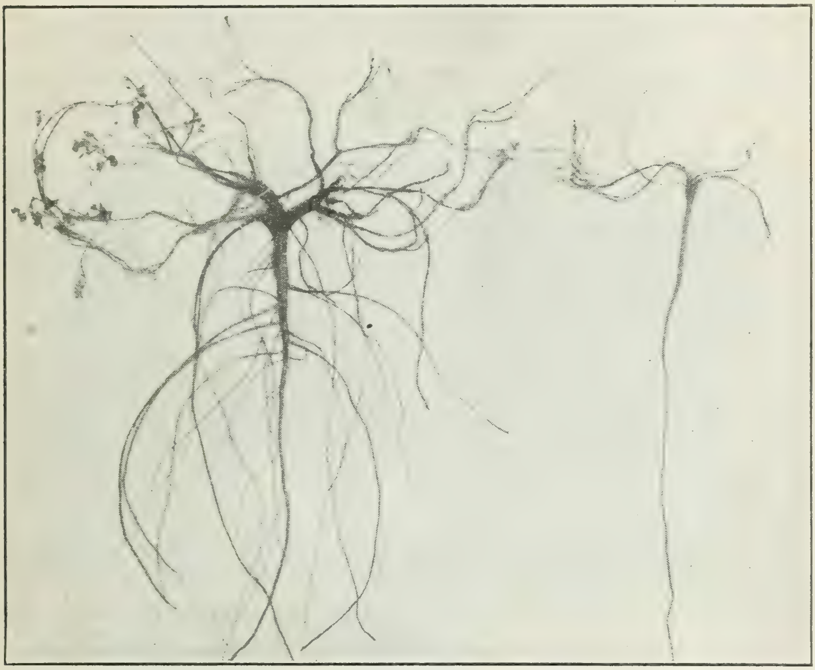

FIG. 17.—Root systems of prostrate yellow-flowered alfalfa plants having distinct taproots, the growth of six seasons.

Root proliferation has been observed in *Medicago falcata* introductions from Orenburg, Russia, and Semipalatinsk, Siberia. This characteristic has also been observed in some hybrid alfalfas. True lateral roots have been found extending parallel to the surface for 36 inches, at a depth of 4 to 12 inches. At irregular intervals the root enlarges to about double its normal diameter. These enlargements or swellings send out aerial shoots and may or may not develop fibrous roots. (Fig. 19.)

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[9] S. P. I. No. 33465 (*Medicago falcata*), from Semipalatinsk, Siberia; presented by G. T. Miroshnikoff, at the request of Frank N. Meyer. Received Feb. 19, 1912.

## SUMMARY.

Factors tending to produce modifications of taproots in alfalfa are soil, climate, cultural treatment, and injuries.

Studies made at Redfield, S. Dak., were on varieties seeded at the same time and grown under the same soil and moisture conditions. Even with the greatest care, however, it is difficult to make allowances for differences in root growth of the various varieties, owing to the nonuniform thinning of the stand by severe climatic conditions or other causes.

The varieties and strains studied include Peruvian, Poona, southern-grown common, northern-grown common, Turkestan, Grimm, and yellow flowered. The root systems of the Peruvian and Poona alfalfas of one season's growth are quite similar. They are characterized by small, upright crowns, distinct taproots, comparatively few branch roots, and few fibrous roots, which are distributed rather uniformly over the root system. They differ in that the Poona seldom has branch roots on the upper portion of the taproot.

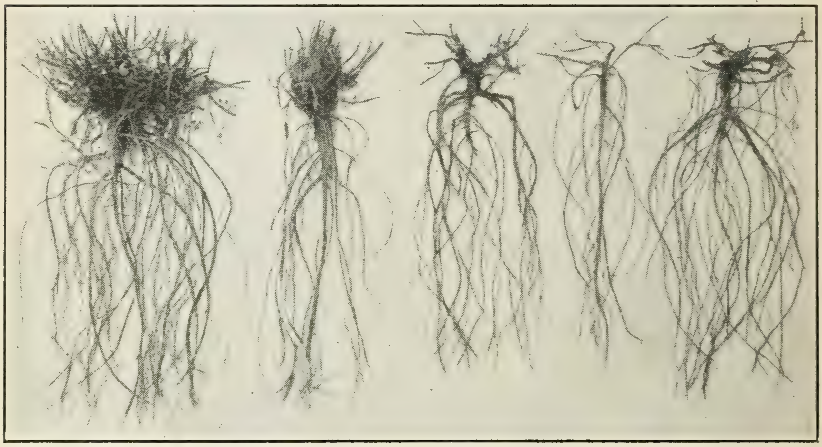

FIG. 18.—Root systems of decumbent yellow-flowered alfalfa plants, the growth of six seasons.

For convenience, the common alfalfas are divided into two classes. the southern-grown common and the northern-grown common. All these alfalfas have distinct taproots and in general show considerable similarity. The northern-grown strains have somewhat broader crowns and they exhibit more of a tendency to throw out branch roots and fibrous roots, but these differences are not sufficiently marked to constitute conspicuous characteristics. Both exceed the Poona and Peruvian alfalfas in branch and fibrous root development. There is practically no difference in the diameter of the taproot.

Turkestan alfalfa is characterized by broader, deeper set crowns, more numerous branch roots, and shorter, more tapering taproots than the common and nonhardy alfalfas. The root system of this alfalfa is very similar to Grimm.

Grimm alfalfa is characterized by broad, deep-set crowns and numerous branch and fibrous roots. There is almost no difference in the diameter of the taproots of Turkestan and Grimm alfalfa, but both somewhat exceed the common and nonhardy strains in this respect. They are also similar in the angle which the branch roots form with the taproot. This angle is greater than in the less hardy varieties studied, but does not constitute a conspicuous characteristic. Fibrous roots are distributed over the root system, and rooting rhizomes are well developed.

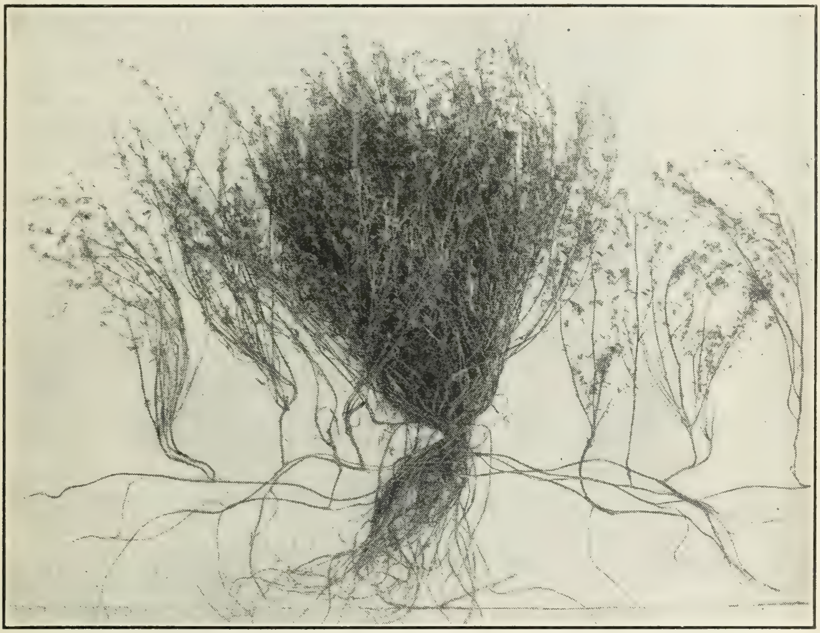

FIG. 19.—New plants that have developed from true lateral roots of yellow-flowered alfalfa.

The forms of *Medicago falcata* are characterized by broad deep-set crowns and an abundant development of fibrous roots and branch roots. They exceed all the other alfalfas studied in these respects. Crown branches and rhizomes are small and numerous. The angle of divergence is greater than in the variegated and common alfalfas. Based upon manner of growth, these alfalfas may be divided into three general classes: The erect, the prostrate, and the decumbent. The erect plants have relatively small but quite distinct taproots and numerous small, slowly tapering branch roots. The prostrate plants have very broad, deep-set crowns, well-developed rhizomes, and dense root systems. Taproots are either absent or very indistinct. The decumbent form is intermediate between the other two forms. The taproots are indistinct, short, and rapidly tapering. This strain had the most extensive root systems of all the alfalfas studied.

A comparison of the different kinds of alfalfa reveals striking differences between certain varieties and strains. There are outstanding differences between the root systems of southern-grown common and yellow-flowered alfalfas in the prominence of the taproots, the development of branch roots, the number and development of rhizomes, and in the number and place of most profuse production of fibrous roots. Between many plants of common alfalfa, especially of the less upright forms, and many plants of the Turkestan and Grimm alfalfas, however, differences are not great, and it is often impossible to determine by their root systems the groups to which these plants belong. In brief, the root systems of the least hardy forms of purple-flowered alfalfa may be distinguished from the most hardy hybrid and yellow-flowered alfalfas with accuracy, but the intermediate forms are not sufficiently distinct to be distinguishable from one another or invariably from some forms of the nonhardy or yellow-flowered alfalfas.

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